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Experimental Studies of Simultaneous 351 nm and 527 nm Laser Beam Interactions in a Long Scalelength Plasma

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Abstract

We describe experiments investigating the simultaneous backscattering from 351 nm (3w) and 527 nm (2w) interaction beams in a long scalelength laser-produced plasma for intensities $\leq 1\times10^{15}$ W/cm^2. Measurements show comparable scattering fractions for both color probe beams. Time resolved spectra of stimulated Raman and Brillouin scattering (SRS and SBS) indicate the effects of laser intensity and smoothing as well as plasma composition and parameters on the scattering levels.

Introduction

Current designs for the National Ignition Facility ignition indirect drive hohlraum have a DT loaded fuel capsule suspended in the center of a gold-walled hohlraum. The hohlraum is filled with a He/H2 gas mixture. Laser beams enter the hohlraum through the laser entrance holes and propagate through the fill-gas to the hohlraum wall where they are converted to x-rays which compress the fuel capsule. Laser propagation through the fill-gas creates a long scalelength high temperature plasma which can cause laser light to be backscattered through stimulated Raman scattering (SRS) or stimulated Brillouin scattering (SBS). It is desirable to minimize the backscattered light from these processes in order to use the laser power efficiently.

Experiments using the Nova laser (references) explored the effects of plasma density, composition, temperature and laser intensity and smoothing in emulator targets to determine how these parameters affected the backscattering. The majority of these experiments used 351 nm laser light (3w) and the targets consisted of gasbags or hohlraums. Gasbag targets emulated the plasma in the central region of the hohlraum and the hohlraum targets emulated the plasma near the hohlraum wall. The experiments were used to validate scattering models which could then be used to extrapolate the laser and plasma parameters to NIF ignition targets.

Interest has recently started to grow over using 527 nm laser light (2w) to drive x-rays in a hohlraum ignition target. Some advantages of this scheme include higher damage threshold for laser optics, more efficient use of the NIF laser, and a larger parameter space of possible ignition target designs. An important consideration in using 2w laser light is the level of backscattering.

In order to assess the 2w backscattering we have undertaken a series of experiments in gasbag targets which simultaneously compare backscatter from 2w and 3w interaction beams. In this paper we report the results of these experiments. We find that at peak electron temperature the 2w SRS remains less than about 15% and the 2w SBS is only a few percent. The 3w scattering is comparable. This level of scattering is for random phase plate smoothing of the beam only. Experiments incorporating SSD and polarization smoothing will indicate how effective these additional smoothing techniques are at further reducing the backscattering.

Laser, target and diagnostic characteristics

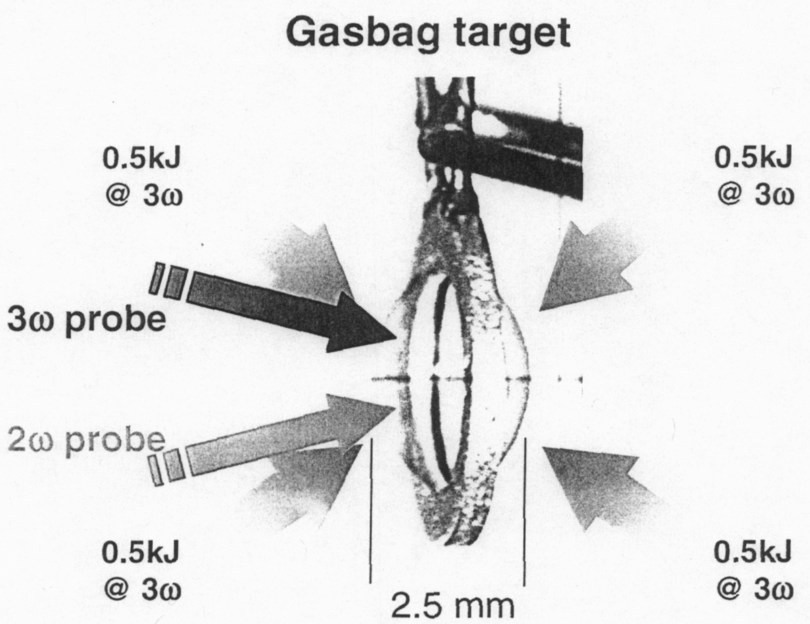

Figure 1. Sketch showing a typical gasbag target with heater beams from both sides and 527 nm and 351 nm probe beams from one side.

The experiments used gasbag targets\cite{\xmcgowan, \xkalan}. A typical gasbag is pictured in Fig. 1. This target consists of two circular polyimide membranes attached to the edges of an aluminum washer. The region between the membranes is filled with a hydrocarbon gas to about 1 atm causing the membranes to expand outward in the shape of a balloon. The fill gasses consist of various CH mixtures with a small fraction of Argon or Xenon dopant. The resulting plasma density is varied between about 5% and 12% of critical density for 351-nm light by changing the gas type and fill pressure.

The experiments were performed using up to 43 beams of the Omega laser at the Laboratory for Laser Energetics at the University of Rochester. 41 beams each with 450 J of laser light at 351 nm in a 1 ns square pulse heated the target. The beams are distributed in 5 different cones on either side of the washer. The two probe beams turn on 0.5 ns after the start of the heater beams. One probe is at 351 nm and the other is at 527 nm. The probe beams have a 1 nm square pulse with variable energy and are smoothed with a distributed phase plate giving a spot size of about 200 microns in vacuum.

Backscattered light from both probe beams is measured using a full aperture backscattered diagnostic. Light collected by the beam focus lens is directed to a set of calorimeters and spectrometers combined with streak cameras which measure the total energy and the time-resolved spectra of SRS and SBS light separately.

X-ray time-gated pinhole images show the gasbag becoming heated throughout by about 0.3 ns after the heater beams turn on. Thomson scattering measurements at 527 nm and 263 nm indicate that the electron and ion temperature within the gasbag plasma are approximately 1.8 keV and 0.54 keV just after the heater beams turn off.

Backscatter measurements

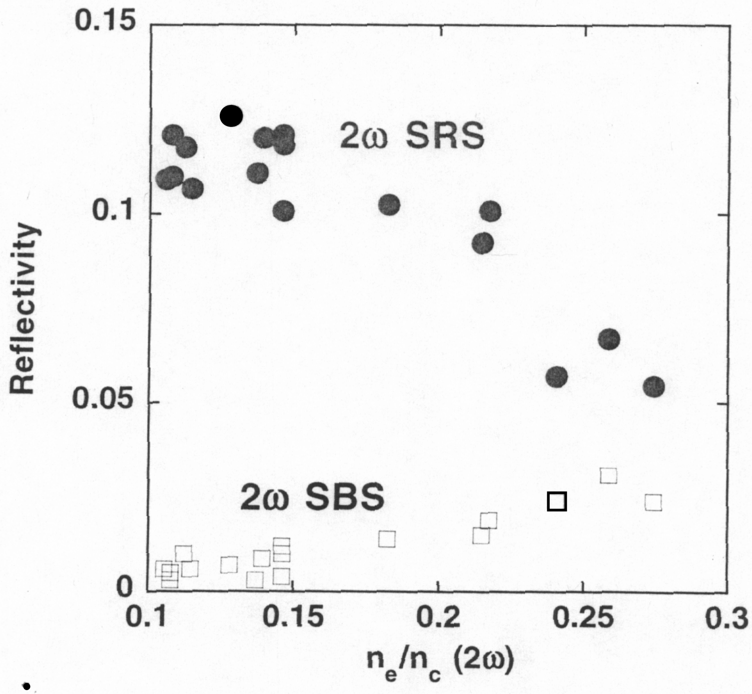

Figure 2. Time-integrated reflectivity of SRS and SBS from the 527 nm probe beam as a function of electron density.

Figure 2 shows the time-integrated SRS and SBS from the 527 nm probe beam as a function of electron density. The SBS scattered light is fairly weak. Time resolved spectra show that the SBS is highest near the turn-on of the 2w probe beam and tends to have a broadened but unshifted spectrum in most cases. Several cases with Xe dopant in the gas showed a SBS spectral shift of about 11 Angstroms. This is consistent with an estimated SBS shift for a 2 keV plasma. The majority of the SBS, however, appears to come from a region of the gasbag plasma that is flowing near the sound speed toward the detector. Time resolved 2w SRS spectra, such as the one shown in Fig. 3, show a narrow spectral width signal early in time with a spectral shift in agreement with the estimated shift using the Langmuir dispersion relation and the measured plasma parameters. Close to the time that the heater beams turn off this narrow band signal remains narrow but shifts toward the blue by about 40 nm. In addition, a spectrally broad signal centered at a shorter wavelength turns on and lasts to the end of the probe pulse length. This broad signal weakens with lower intensity suggesting that it is linked to filamentation which is excited more easily in the cooling plasma due to the absence of the heater beams.

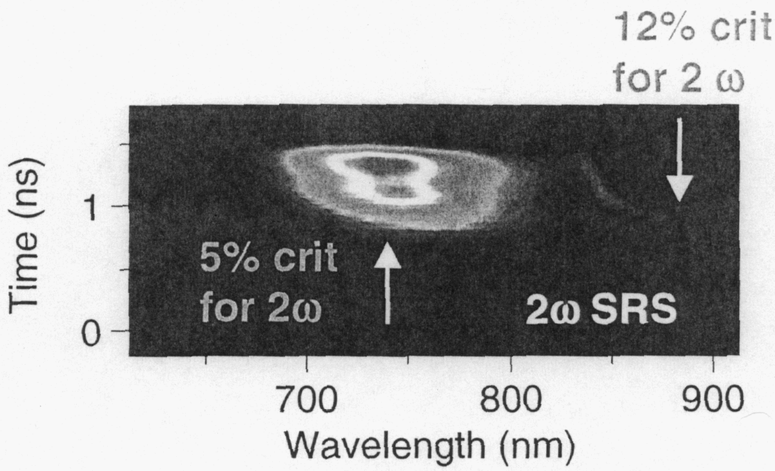

Figure 3. 2w SRS spectra showing signal from the main plateau region (12% critical) and signal centered at 740 nm probably caused by filamentation.

The majority of the SRS comes from the late time broad spectral portion. Time resolved analysis of the SRS data shows SRS scattering at 1 ns which is slightly lower than the values plotted in Fig. 2. The time of 1 ns is important since this is just before the heater beams turn off and the plasma electron temperature is at its peak.

Summary

Experiments in long scalelength plasmas using 351 nm and 527 nm probe beams show favorable backscattering values for 527 nm. The SRS scattering level does not exceed 15% at a probe intensity of about 1 x 10^{15} W/cm^2. The scattering decreases rapidly with lower intensity. The SRS spectra indicates that only a small portion of the scattered power is due to SRS from the plateau density region of the plasma. Most of the scattered power is in a broad spectral region corresponding to lower electron densities than in the plateau. This may result from filamentation in either the main plasma or the blow-off region. Future experiment will explore the effects of SSD and polarization smoothing as well at try to understand some of the detailed features in the scattered power spectra.